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Multi-Project Baselines for CDM Projects: Case Study for the Cement Industry in China

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Abstract

Using the methodology of multi-project baseline for CDM projects developed by the Lawrence Berkeley National Laboratory (USA), a case study for the cement industry in China was conducted. Data for six kilns were collected for the baseline calculation. Five hypothetical CDM projects were used for testing the methodology.

This paper presents the result of the analysis. It shows that the methodology requires some modifications based on China's data situation. Instead of plant-based baselines as originally envisioned, kiln-based baselines are more appropriate for China. Specifically, kilns with advanced domestic technology should be used for the baseline calculation. Then, in order to meet the requirement of additionality, CDM projects must adopt imported advanced technologies in China. Mitigation can be achieved through fuel reduction in the kiln and electricity efficiency improvement**.** Fuel switching from coal to other low-carbon fuels can increase CO_2 reductions. Other measures besides energy-efficiency improvement, such as blending, should be included in cement CDM projects

1. Introduction

From the perspective of carbon dioxide (CO_2) emissions, the cement industry is an unique special sector that emits CO_2 not only from energy consumption, but also from the production process (raw materials). The level of emissions from the production process is almost same as that from energy consumption. China is the largest cement producer and consumer in the world. CO_2 mitigation can be achieved in the cement industry through energy-efficiency improvement as well as through cement utilization reduction, which includes such measures as increasing cement utilization efficiency, reducing clinker consumption for cement production, and replacing cement by other materials for construction.

In December 1997, the third Conference of the Parties (COP3) to the United Nations Framework Convention on Climate Change (UNFCCC) was held in Kyoto. Industrialized countries (i.e. Annex 1 countries) agreed to reduce their greenhouse gas (GHG) emissions, in the 2008-2012 commitment period, by at least 5% below 1990 levels. In order to reduce the cost of mitigation, Article 12 of the Kyoto Protocol makes provisions by which those signatories who are required to limit emissions can gain credit for financing cost-effective mitigation projects in developing countries, while at the same time promoting sustainable development through the provision of financial and technical assistance. The Clean Development Mechanism (CDM) is one of three flexibility mechanisms for emission reductions that were adopted as part of the Kyoto Protocol.

Additionality is the first measurement to judge a project qualifying under the CDM. There are several prerequisites associated with the determination of a CDM project'semission reduction levels, such as project boundaries, in which the definition of baseline plays an important role for evaluating a CDM candidate project.

The cement industry is a favorable sector for CDM implementation. In general, there is a large potential for energy-efficiency improvement in China because most of the cement plants use outdated technology and equipment. But there are numerous large-scale plants now adopting advanced technology and using imported equipment. The performance and energy efficiency of these plants are much better than the average Chinese cement plant.

If CDM is implemented in the future, the candidate project selection in the cement industry will heavily depend on the baseline calculation. For this case study, we use data from six large-scale plants to construct a multi-project baseline. This baseline calculation indicates that the CDM candidate projects should adopt international advanced technologies in order to meet the requirement of additionality. Domestic technologies only can beat an average multi-project baseline.

2. Background of the Cement Industry in China

China's first cement plant was built in 1889, just 18 years after the first Portland cement plant in the U.S. started operation. Since then, China's cement output has increased continuously. Growth in cement production was very fast, especially during the last two decades. In 1985, China became the largest cement producer in the world. Now China's cement output accounts for more than one third of total worldwide. From the following tables, one can follow the development trajectory of the country's cement industry and its characteristics.

2.1 Fast growth rate of cement production

Table 1 shows the cement output and its growth rate. Cement production in China grew at an average rate of about 10% from 1980 to 1999, higher than that of the gross domestic product (GDP) (about 9.4%).

Table 1. Cement production in China, 1950-1999 (million tons)

Year	Cement output	Annual growth rate (%)	Year	Cement output	Annual growth rate (%)
1950	1.41		**1989**	210.29	0.0
1960	15.65	27.2	**1990**	209.71	-0.0
1970	25.75	5.1	**1991**	252.61	20.5
1980	79.86	12.0	**1992**	308.22	22.0
1981	82.90	3.8	**1993**	367.88	19.4
1982	95.20	14.8	**1994**	421.18	14.5
1983	108.25	13.7	**1995**	475.61	12.9
1984	123.02	13.6	**1996**	491.19	3.3
1985	145.95	18.6	**1997**	511.74	4.2
1986	166.06	13.8	**1998**	536.00	4.7
1987	186.25	12.2	**1999**	573.00	6.9
1988	210.14	12.8			

Source: State Statistical Bureau, 2000

2.2 Rapid increase of small cement plants

Because of the high demand, many small-scale cement plants were built through township and village enterprises. At the end of 1997, there were 8435 cement plants with a total capacity of 660 million tons of clinker per year. There were only 576 large-scale plants with an annual output larger than 200,000 tons each. To date, China only has 17 kilns with a capacity larger than 3000 tons of clinker per day. The largest is 7200 tons per day in the Dayu Cement Plant that was jointly constructed with a foreign company. Kilns with capacities of 700, 1000 and 2000 tons per day number 36, 27 and 29, respectively. There are 5115 small-scale plants with annual outputs of 50,000 tons and below. These small-scale plants have low product grades, low productivity, and are energy- and pollutant-intensive. In 1998, the State Council decided to shut down 4247 small cement plants with 5063 kilns and capacities of 1000 million tons in 1999 and 2000 to restructure the cement industry, reduce energy consumption, protect local environment and control total output. Tables 2 and 3 show China's cement industry production mix by plant size.

Most cement plants have several small capacity kilns. Some plants keep the small kilns running even after they have constructed a new large-scale kiln. Table 4 shows the difference in capacity per kiln between China and Japan.

Table 2. China's cement production mix by plant size

Year	Total cement output (Mt)	Production by large-medium size plants (Mt)	Proportion of large-medium size plants (%)
1960	15.65	11.01	70.35
1965	16.34	11.06	67.69
1970	25.75	15.17	58.91
1975	46.26	19.09	41.27
1980	79.86	25.58	32.03
1985	159.55	32.35	20.28
1990	209.71	39.86	19.01
1997	511.74	75.40	14.73
1998	536.00	88.40	16.49
1999	573.00	115.60	20.17
2000 (estimated)	576.00	203.90	35.40

Source: State Statistical Bureau, 1992; State Statistical Bureau, 2000.

Table 3. Cement production by kilns in China (1999)

Kiln type	Units	Capacity (tons/d-set)	% total cement output
NSP kiln (large scale)	109	700-7200	8.3
NSP kiln (small scale)	96	300-600	1.1
Preheater kiln (large)	3	800-1000	0.1
Preheater kiln (small)	72	100-300	0.3
Preheater vertical	295	200-400	1.8
Semi-dry	9	700-2000	0.6
Inner hollow kiln	109	500-1000	2.0
Libor kiln	20	400-600	0.5
Wet rotary kiln	206	400-800	6.1
Vertical kiln	12000	50-350	77.7
Total	13259		100.0

Source: *China Building Material* No. 5, 2000

Note: NSP kilns are the most efficient kilns and have both suspension preheaters and precalciners.

Table 4. Comparison of annual capacity per kiln between China and Japan

	Year	China	Japan
Number of kilns	1987	2871	96
	1990	3912	81
	1997	about 14300	--
Annual capacity (k ton)	1987	204670	97221
	1990	268890	87808
	1997	660165	--
Average annual capacity per kiln (k ton)	1987	71	1013
	1990	69	1084
	1997	47	--

Source: *Cement No. 1, 1993*, *China Building Material* No. 5, 2000

2.3 Cement production satisfies domestic demand

Due to continued cement plant construction, China stopped importing cement in 1990. Cement production has been able to satisfy domestic demand even in recent years when the government has increased investment for infrastructure construction. Currently, China is a net exporter of cement. Considering the energy consumption and pollution issues, some developed countries have decreased domestic cement production and are now importing cement and clinker from China. For example, in 1998, about 2 million tons of cement and 200 thousand tons of clinker were exported from China to the U.S.

2.4 Low energy efficiency and unbalanced technology development

In general, the energy intensity of cement manufacturing in China is much higher than in developed countries. Table 5 shows the differences in specific energy consumption between China, Japan, and former West Germany. However, the complete situation in China is quite complicated because there are about 8000 plants. Table 6 shows the energy intensity for different kilns in China. It shows that the energy intensity of the best plant in China only reaches the world level of late 1980s.

Table 5. Comparison of specific energy consumption for cement production in Japan, former West Germany, and China

Country	Year	Heat intensity (MJ/ton clinker)	Elec. Intensity (kWh/ton cement)	Integrated energy intensity (MJ/ton cement)
Japan	1980 1990	3524 2947	124 102	3973 3311
Former West Germany	1980 1990	3219 2625	104 104	3592 3001
China (large and medium size plant)	1980 1990	6040 5433	97 110	6120 5990

Source: State Administration of Building Material Industry of China, 1992

Table 6. Energy intensity by kilns in China (1999)

Kiln type	Energy intensity (MJ/ton clinker) Average/Best		Electricity Intensity (kWh/ton cement) Average/Best	
NSP kiln (large scale)	3427	3135	115	105
NSP kiln (small scale)	4598	3762	130	115
Preheater kiln (large)	4640	3887	125	120
Preheater kiln (small)	4891	4389	125	120
Preheater vertical	4974	4598	125	120
Semi-dry	3846	3553	105	100
Inner hollow kiln	7106	6604	120	110
Libor kiln	4723	4159	120	115
Wet rotary kiln	6124	5768	105	95
Vertical kiln	5500	3658	115	67

Source: *China Building Material* No. 3, 2000.

2.5 Coal as the main fuel

Cement production uses only coal as the kiln fuel in China. Coal accounted for 80% of total cement production energy consumption. Because coal-fired power plants generate almost four-fifths of total electricity in China, the carbon intensity for cement production is much higher than other countries. Table 7 shows the energy consumption of cement production in China.

Table 7. Energy consumption of cement industry in China

Year	**1990**	**1995**	**1997**
Cement output (Mt)	210	476	513
Energy consumption (Mtce)	410.71	87.28	93.21
Of which:			
coal (Mtce)	32	68	73
elec.(GWh)	21370	47600	49200
oil (k ton)	150	--	--

Source: *China Energy* No.7, 2000.

2.6 CO_2 emissions

From the perspective of CO_2 emissions, the cement industry is a special sector that emits CO_2 from both energy consumption and the production process. It is estimated that the cement industry emitted 43.33 million tons of CO_2 (in tC) in 1990 of which 50% was from the production process and 50% was from energy consumption. In 1997, emissions reached 102 million tons of CO_2 (tC).

There are several studies conducted by Chinese researchers on CO_2 emissions from non-energy activity in the cement industry. These studies have a slightly different emission factor due to the use of different data. One study indicated that one ton of clinker contains 0.62 tons of CaO, and one ton of cement consumes 0.75 tons clinker (*China Energy*, No 7, 2000). Thus, the emission factor is: 0.62* (44/56) * 0.75 = 0.3654 ton-CO_2/ton cement.

Another study indicated that one ton of clinker consumes 1.157 ton $CaCO_3$ and one ton of cement requires 0.739-ton clinker. The emission factor is: 1.157 * (44/100) * 0.739 = 0.3762 ton-CO_2/ton cement (Research Team of the China Climate Change Country Study, 1999).

The difference in CO_2 emissions from energy use in the cement industry mainly comes from its electricity consumption. If CO_2 emissions from electricity consumption are included as part of total emissions from the cement industry, then the different sources of power generation should be considered. Emission data for the cement industry in China typically are only the emissions from fuel consumption, excluding electricity consumption. Table 8 shows the estimated CO_2 emissions from the Chinese cement industry.

2.7 Development target

In order to improve energy efficiency and reduce the various emissions from cement plants, the Chinese government plans to limit total cement output to no more than 600 million tons per year. There will be a focus on restructuring the cement industry by replacing small-scale cement plants by large-scale NSP kilns with high efficiency. In 1999 and 2000, there were 4247 small cement plants in which 5063 kilns were closed. Now, newly built kilns must be larger than 4000 tons/day in the east coast areas and 2000 tons/day in the central and western areas. It is planned that at the end of years 2005 and 2020, 110 and 450 million tons of cement will be produced by NSP kilns, accounting for 20% and 75% of total output of each year, respectively. NSP kilns produced 8.3% of total cement output in 1997.

Table 8. CO_2 emissions of the cement industry (million tons C)

Year	1990	1995	1997
From fuel consumption	22.46	47.63	51.32
From process	20.87	47.38	51.04
Total emission	43.33	95.01	102.37

Source: *China Energy* No.7, 2000

3. Multi-Project Baselines for Cement Production

3.1 Data availability

During the past two decades, supported by domestic commercial banks, the Asian Development Bank, the World Bank, and other financial sources, some cement plants introduced advanced technologies and equipment to retrofit their plants. Even so, most of the plants kept their old kilns for production. There are two reasons for keeping the old kilns running: first, cement sales were high and second, the jobs were needed.

Thus, these plants have two or three generations of kilns such as wet process kilns, vertical kilns and NSP kilns. In order to represent the best available technology, all data we collected are based on the newest generation of kiln in the plants. These kilns have run for several years with steady operation. These kilns represent the present situation of advanced technology of the cement industry in China.

Data for six kilns were collected from six cement plants. These plants are located nation-wide. They consume various kinds of coal and electricity from different power grids. There are eight independent power grids in China. The sources for power generation are quite different. Some grids include more hydropower than others. According to statistics, 1080 TWh of electricity was generated in 1996, in which 17% was hydropower, 1% nuclear and 82% thermal as shown in Figure 1, Table 9 and Figure 2 show the fuel consumption for thermal power plants in 1996. In order to simplify the multi-project baseline calculation, the national-level fuel mix for electricity generation was used to calculate the carbon content of electricity for this analysis. The electricity carbon content in China is much higher than those countries that use more hydro and low carbon content fossil fuel such as natural gas and fuel oil for power generation. Electricity efficiency improvement is an important measure for CO_2 reduction in the cement industry in China.

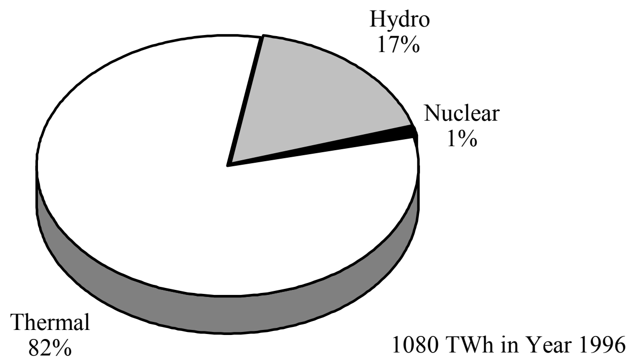

Figure 1. Power generation mix

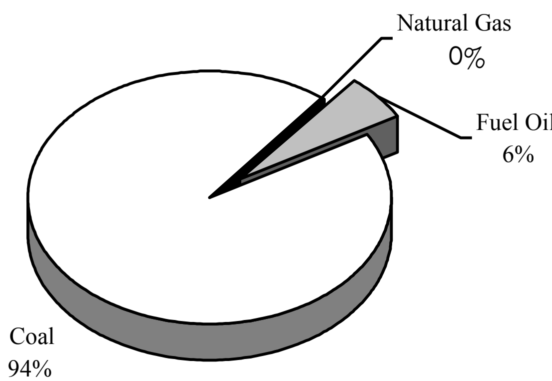

Figure 2. Thermal power fuel mix

Table 9. Fuel mix for power generation (1996)

Coal	8913	PJ
Natural Gas	338	PJ
Fuel Oil	438	PJ
Electricity	1080	TWh
Carbon content	0.226	kg C/kWh

Source: State Statistical Bureau, 1998.

Six types of data are needed for the multi-project baseline calculation. They are:

1 - annual throughput at raw materials grinding stage (Mtonne)
2 - annual electricity use for grinding raw materials (GWh)
3 - annual production of clinker (Mtonne)
4 - annual energy use of specific fuels for clinker production (GJ)
5 - annual throughput at cement grinding stage (Mtonne)
6 - annual electricity use for grinding cement (GWh)

In addition to the above data, four indicators are used to present the energy consumption and cement production situation in cement plants in China. They are:

1 - annual production of clinker (Mtonne)
2 - annual energy use of specific fuels for clinker production
3 - annual production of cement
4 - annual electricity use for whole production process

According to studies (Mohanty, 1997), the electricity consumption for the cement plant can be divided into three stages: raw material preparation (before kiln), clinker production (during kiln) and finishing (after kiln). Figure 3 shows the general situation of electricity consumption by process. One case study shows the mills for blending raw material, coal, clinker and cement consume 20.1 kWh per ton of raw material, 36.5 kWh per ton of coal, 31.5 kWh per ton of clinker and 32 kWh per ton of cement, respectively (NCDRI, 1994)). Comparing the data between Figure 3 and Table 10, it shows that the electricity consumption in raw material grinding stage in baseline calculation includes the consumption in first two stages. Converting the data the plant has to the data required for the baseline calculation is based on expert judgement.

Table 10. Six-baseline kilns energy and carbon intensity

Kiln No.	**1**	**2**	**3**	**4**	**5**	**6**
Capacity (t clinker/day)	4000	4000	2000	2000	4000	2000
Energy	Coal & Electricity					
Raw Material Grinding Stage						
Energy intensity (kWh/tonne)	68.81	66.67	70.19	69.06	70.64	73.04
Carbon intensity (kg C/tonne)	15.55	15.07	15.86	15.61	15.97	16.51
Clinker Production Stage						
Energy intensity (GJ/tonne clinker)	3.37	3.28	3.03	3.77	3.13	3.77
Carbon intensity (kg C/tonne clinker)	88.80	86.35	79.89	99.25	82.46	99.29
Cement Grinding Stage						
Energy intensity (kWh/tonne cement)	40.50	32.45	45.20	39.47	33.00	42.49
Carbon intensity (kg C/tonne cement)	9.15	7.33	10.22	8.92	7.46	9.60

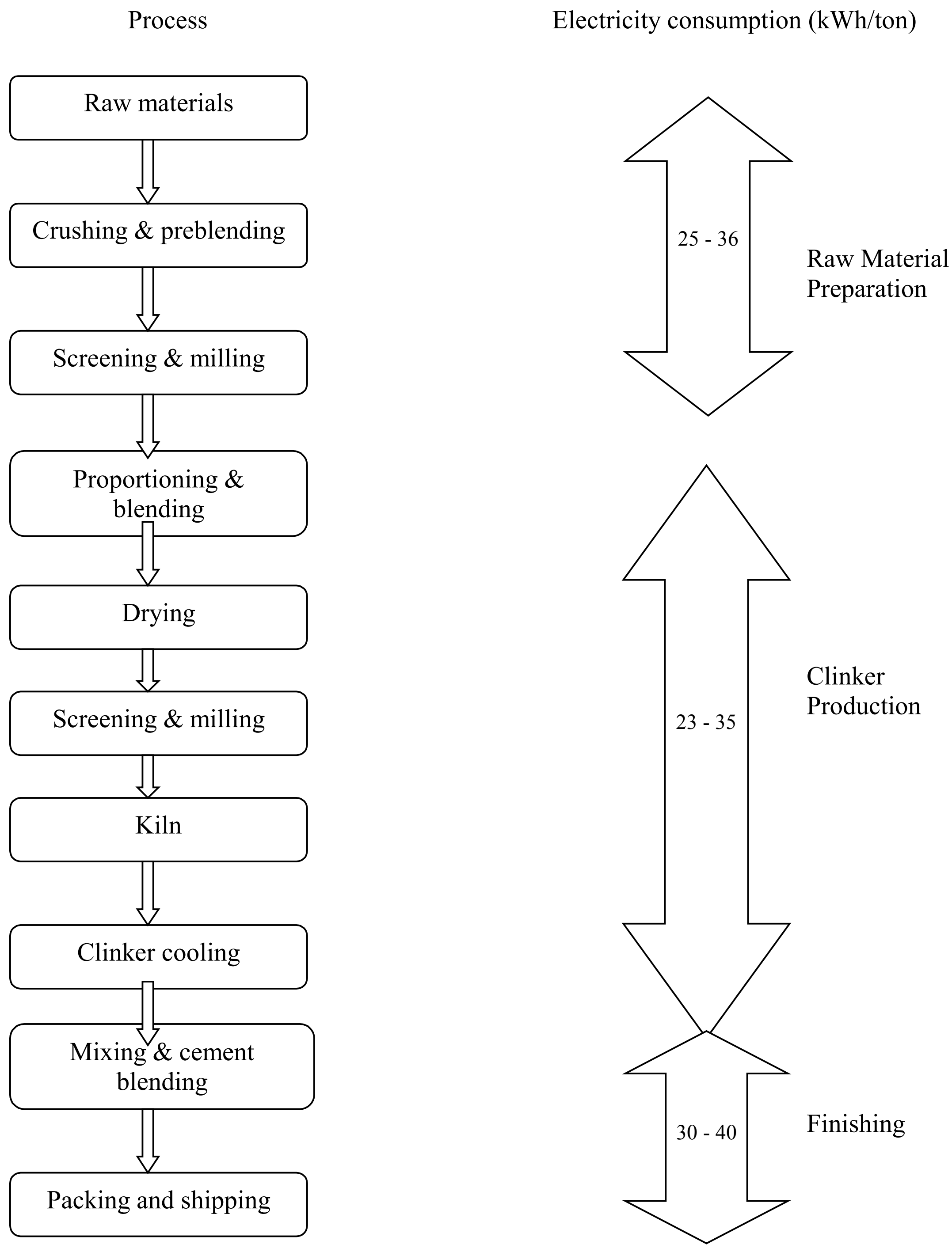

Figure 3. Electricity consumption by process

3.2 Multi-project baseline calculation

Based on the data for the six kilns, the baseline intensities were calculated as shown in Table 11 and Figure 4. We analyzed five different multi-project baselines based on the average performance of the kilns in our sample, the weighted average performance, the 25th percentile, the 10th percentile, and the best plant. Because of the small number of plants used for the multi-project baseline calculation, the baseline intensity of the 10th percentile is the same as that of the best plant. This illustrates that the benchmark is heavily dependent upon the kiln data used. Which kilns are selected is very important for the benchmark calculation. Among the six kilns, three kilns are imported and have capacities of 4000 tons per day. The others are domestically made with capacities of 2000 tons per day. There is no plant that is the best at all three stages.

The carbon intensity of the clinker production stage is much higher than the other stages. The carbon intensity by electricity consumption (both in raw material grinding and cement grinding) is about one fifth of clinker production. Up to now, coal is the only fuel used for clinker production kilns in China. There is no difference in fuel-specific and sector-wide calculations.

Table 11. Baseline intensity

	Benchmark Basis:	**Average**	**Weighted Average**	**Percentile 25%**	**Percentile 10%**	**Best Plant**
Raw Material Grinding Stage						
carbon intensity	kg C/tonne	15.76	15.71	15.17	15.07	15.07
Clinker Production Stage						
carbon intensity	kg C/tonne	87.47	85.92	79.22	78.22	78.22
Cement Grinding Stage						
carbon intensity	kg C/tonne	8.78	8.72	7.36	7.33	7.33

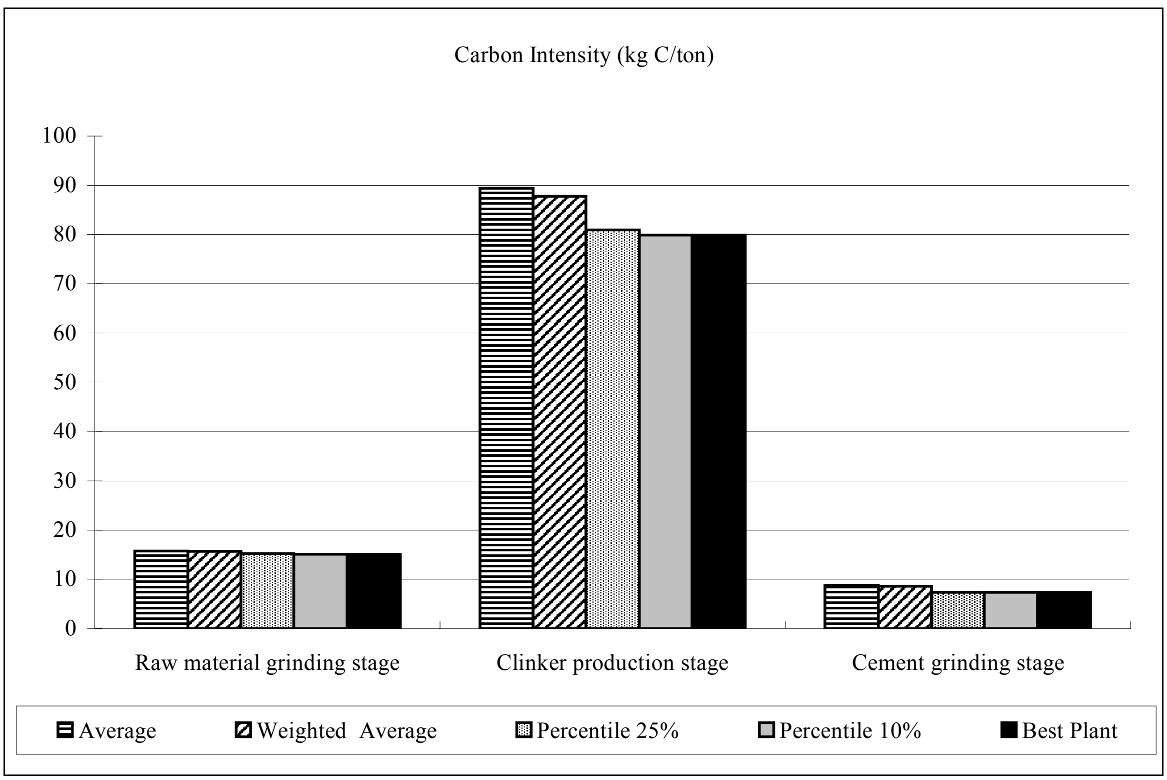

Figure 4. Baseline Intensity

4. Assessment of Hypothetical Cement CDM Plants

The objective of this analysis is to test the use of a multi-project baseline for CDM candidate project assessment. Based on the following considerations, five hypothetical projects were selected for CDM project implementation. Table 12 provides the energy intensity values for these five projects.

Projects #1 and #3 will adopt advanced domestic technology with the capacity of 4000 tons per day. Project #3 has higher electricity efficiency than Project #1 for testing the impact delivered by electricity-efficiency improvement. Projects #2, #4 and #5 will adopt imported technology with the capacity of 7200 tons per day. Different fuels will be used in these three projects for testing the impacts of fuel switching. Table 12. Energy intensity for the five hypothetical CDM projects

PLANT NAME		**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
Capacity (ton/day)		4000	7200	4000	7200	7200
Hypothetical		Advanced domestic technology	Imported technology	Domestic technology combined with electricity efficiency improvement	Imported technology and mix fuel (50% coal and 50% NG)	Imported technology and fuel switch (100% NG)
Raw Material Grinding Stage						
energy intensity	kWh/ton	64.00	46.00	46.10	46.00	46.00
Clinker Production Stage						
energy intensity	GJ/ton	3.13	3.00	3.13	3.00	3.00
Cement Grinding Stage						
energy intensity	kWh/ton	35.00	30.00	30.10	30.00	30.00

Table 13 provides information on NSP kilns. NSP kilns are the most efficient kilns currently available and have both suspension preheaters and precalciners. In general, larger scale kilns have higher fuel efficiency and lower investment intensity, as shown in Table 13. The largest existing kiln in China is 7200 tons/day. It is assumed that kilns of 7200 tons/day or larger will be imported in the future.

In order to reduce the cost, many studies have been conducted in order to be able to produce the imported equipment domestically. China can now make most of components of a 4000-ton/day kiln. The Chinese government now expects the 4000 tons/day kilns to be the main size of kilns for new construction. In the east cost areas, the more developed areas in China, new kilns must be 4000 tons/day or larger. Many 4000 ton/day kilns will be built to replace the old small-scale kilns in the near future.

Although electricity is a small part of energy consumption during the cement process, improving electricity efficiency is valuable to reduce carbon emissions because coal-fired power plants are the main facilities for generation in China. Two hypothetical CDM projects are considered based on different electricity efficiencies and the same fuel efficiency.

Currently, coal is the only fuel used in kilns. As the natural gas resource is developed, especially the “west–to-east” natural gas project that will be completed in 2003, it will be possible to replace coal by natural gas for cement production. Two CDM projects present the fuel switching situations, one is replacing 50% coal by natural gas and the other is using 100% of natural gas.

Table 13. NSP kiln characteristics by size

NSP kiln capacity (t/d)	4000	2000	1000
Percentage of domestic made equipment (%)	80-90	90	100
Investment (US $/ton cement)	60-65	65	65
Energy intensity (kJ/kg clinker)	3093-3153	3153-3177	3302-3428
(kWh/t cement)	98	100	105

Table 14 shows the carbon intensity of the five hypothetical CDM projects. It shows that comparing Projects #1 and #2, as the capacity scale is increased, the fuel and electricity efficiency improves, and the carbon intensities decrease in different stages. Carbon emission reduction can also be achieved by improving electricity efficiency only, as in Projects #1 and #3. The largest carbon emission reductions can be gained by using clean energy. The more low-carbon fuel used, the more mitigation achieved (see Projects #2, #4 and #5).

Table 14. Carbon intensities of five hypothetical CDM projects

PLANT NAME		Project 1	Project 2	Project 3	Project 4	Project 5
Capacity (ton/day)		4000	7200	4000	7200	7200
Raw Material Grinding Stage						
carbon intensity	kg C/ton	14.46	10.40	10.42	10.40	10.40
Clinker Production Stage						
carbon intensity	kg C/ton	80.75	77.40	80.75	61.65	45.90
Cement Grinding Stage						
carbon intensity	kg C/ton	7.91	6.78	6.80	6.78	6.78

5. Results

Table 15 compares the performance of hypothetical CDM projects against different multi-project baselines. A positive number indicates that the hypothetical CDM project has lower carbon intensity than the baseline. The larger the number, the better the performance in terms of carbon intensity. Only projects with positive values are viable CDM projects.

Present domestic advanced technology, as represented by Project #1, can only beat the average benchmark. If better-than-average benchmarks are used, there are no energy savings or carbon savings for these plants in either the fuel-specific or sector-wide cases. Domestic advanced technology with additional electricity-efficiency improvements, as represented by Project #3, are better than all of the benchmarks from a total plant point of view, although the carbon reduction of clinker production is lower than the better-than-average benchmarks. This means that electricity efficiency is an important reduction measure because of the reliance on coal as the main source for power generation. This conclusion is made based on the nation-wide power source mix; for some areas where more hydropower is used for electricity production, there may be no carbon reduction benefits through electricity-efficiency improvement.

Imported advanced technology, as represented by Project #2, is better than all of the benchmarks.

Huge carbon reduction benefits can be gained if the plant uses more low-carbon fuel to replace coal. Fuel switching away from coal, as represented by Project #4 (50% coal and 50% natural gas) and Project #5 (100% natural gas), gives the largest carbon emission reductions. However, since coal is currently the only fuel used for kilns, we can't compare the CDM project to benchmarks from the fuel-specific point of view and only the sector-wide calculation is available.

6. Conclusions

Based on the analysis of five hypothetical CDM cement projects using a multi-project baseline approach, we have the following conclusions:

6.1 Methodology modification

There are two indicators currently used to measure the energy consumption or efficiency in cement plants in China. They are specific fuel consumption for clinker production and integrated electricity consumption for cement production. If the methodology developed by LNBL is used in China, we should change data collection requirement based on China's data situation. It is suggested that the following data be required for the baseline calculation.

1 - annual production of clinker (Mtonne)
2 - annual energy use of specific fuels for clinker production (GJ)
3 - annual production of cement (Mtonne)
4 - annual electricity use for whole production process (MWh)

6.2 Data availability

There is no database for the cement industry in China related to energy consumption. Data should be collected on a plant-by-plant basis, which is a time- and cost-consuming work. If the methodology is not changed for data collection as suggested above, it is very difficult to get data related to electricity consumption divided to different stages. Also, there is an absence of electricity consumption for kilns in the methodology.

6.3 Kiln-based baselines are appropriate for China

Some cement plants run several kilns, each with different efficiencies. For example, one plant selected for the baseline calculation runs four kilns: one vertical kiln, two wet process kilns and one NSP kiln. The performance and energy efficiency of these kilns are quite different. The general data from the plant usually presents the average performance, which hides the significant differences in efficiency. Thus, it is important that kiln-based data be collected for the baseline calculations.

6.4 Kilns for baseline calculations must be selected carefully

It is not simple to understand the kiln's technology levels based on its construction date in China. The technologies the plant adopted depend on financial resources. The domestic, cheaper but not state-of-the-art technologies will be adopted by those plants with limited funds. Normally, the projects supported by international financial organizations or listed in the official key project construction plan, have sufficient funds and can adopt international advanced technologies. The performance of these plants is better than the plants under construction or even planned plants. On the other hand, due to management, personal capacity and mastering know-how, the performance of similar kilns can be quite different in different plants. Some old kilns run better than the newly-built kilns. Which kilns should be used for establishing multi-project baseline is an important topic for further research. The better the kilns' data (kilns with higher energy efficiency) we adopt for calculation, the lower the carbon intensity the baseline has. If the baseline has very low carbon intensity, there will be a few candidate projects that can meet the additionality criterion.

The data from kilns with advanced domestic technology level should be collected for the baseline calculation because a CDM project should benefit non-Annex 1 countries in terms of technology, capital and know-how transfer. If we use the data from imported advanced kilns, it is unlikely that any CDM projects will occur.

Another area to evaluate is how many kilns will be used for the baseline calculation. If only ten or fewer kilns are used for the calculation, there is no difference between 10% percentile and best plant baseline.

6.5 CDM projects should adopt international advanced technologies

In order to meet the requirement of additionality, CDM projects must adopt imported advanced technologies that can beat all benchmarks according to the baselines established in this research. The projects adopting advanced domestic technology can beat only the average and weighed average baselines. The question is if a CDM project is implemented that adopts international advanced technologies, shall we calculate the baseline again using the new data? If we do, the best plant must represent the new kiln and no other kilns will then be able to beat the best plant baseline.

There are only six kilns' data for baseline calculation. This is not enough for commenting on which baseline level we should adopt for evaluating a CDM candidate project. In general, a 10% percentile baseline may be good for CDM project evaluation because it can eliminate the outliers in data collecting. At the same time, it can identify the present advanced technology of non-Annex 1 countries and assist in realizing technology transfer.

6.6 Mitigation can be achieved through fuel reduction in the kiln and electricity efficiency improvement

There is no doubt that carbon emissions can be reduced through improving fuel efficiency in the kiln. Since coal is the main source of power generation, there is an associated carbon reduction through electricity-efficiency improvement. But when we analyze CO_2 emissions by sector, the emissions from power generation are typically included in the power industry. The cement industry emission data used above do not include the indirect emissions from electricity consumption.

6.7 Fuel switching from coal to other low-carbon fuel can increase CO_2 reductions

Using low-carbon fuel for kilns and power generation can increase CO_2 reductions. The issue is how to develop low-carbon resources and markets. For example, after the west–to-east natural gas project is completed, it can supply 12 billion cubic meters of natural gas to Shanghai, the more developed area in China. The price of natural gas is estimated to be 0.16 US$ per cubic meter which is higher than in most developed countries. The industries, however, want to pay 0.13 US$ per cubic meter. Overcoming such barriers to promote natural gas utilization is currently a big topic in China.

6.8 Other measures besides energy efficiency improvement should be included in cement CDM projects

The cement industry is one of a few sectors that emit CO_2 not only from energy consumption but also from the production process. The emissions from the production process are almost equal to those from energy consumption. Improving energy efficiency can only solve part of problem. Reductions in cement utilization or in the clinker consumption for cement production are effective measures for CO_2 reduction. For example, some kinds of slag from the metallurgical industry have special characteristics that can blend with clinker to produce cement and improve the quality of cement. According to a rough estimate, if the cement output target is 600 million tons per year in the next two decades, 1% more slag will be used for cement production than is currently used and as a result 0.8 million ton-C of CO_2 will be reduced from clinker production process. CDM should also pay attention to such measures.

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Table 15. Decrease in carbon intensity from CDM projects against baselines

Project #1			***Energy/carbon reductions relative to various benchmarks*** *(project performs this much lower than benchmark)*				
PROCESSES:		**Project Performance**	Average	Weighted Average	Percentile 25%	Percentile 10%	Best Plant
Raw Material Grinding							
energy intensity	kWh/tonne	64	5.73	5.5	3.1	2.67	2.67
carbon intensity	kg C/tonne	14.46	1.3	1.24	0.7	0.6	0.6
Clinker Production							
Fuel-Specific							
energy intensity	GJ/tonne	3.13	0.26	0.2	-0.06	-0.1	-0.1
carbon intensity	kg C/tonne	80.75	6.72	5.17	-1.53	-2.53	-2.53
Sector-Wide							
energy intensity	GJ/tonne	3.13	0.26	0.2	-0.06	-0.1	-0.1
carbon intensity	kg C/tonne	80.75	6.72	5.17	-1.53	-2.53	-2.53
Cement Grinding							
energy intensity	kWh/tonne	35	3.85	3.59	-2.44	-2.55	-2.55
carbon intensity	kg C/tonne	7.91	0.87	0.81	-0.55	-0.58	-0.58
PLANT TOTAL:							
Fuel-Specific							
Energy Savings	TJ		517.2	433.2	None	None	None
	GJ/tonne cement		0.38	0.31	None	None	None
Carbon Savings	Ktonne		12.4	10.2	None	None	None
	kg C/tonne cement		8.97	7.43	None	None	None
Sector-Wide							
Energy Savings	TJ		517.2	433.2	None	None	None
	GJ/tonne cement		0.38	0.31	None	None	None
Carbon Savings	Ktonne		12.4	10.2	None	None	None
	kg C/tonne cement		8.97	7.43	None	None	None

Table 15. Decrease in carbon intensity from CDM projects against baselines (continued)

Project #2			***Energy/carbon reductions relative to various benchmarks*** *(project performs this much lower than benchmark)*				
PROCESSES:		**Project Performance**	Average	Weighted Average	Percentile 25%	Percentile 10%	Best Plant
Raw Material Grinding							
energy intensity	kWh/tonne	46	23.73	23.5	21.1	20.67	20.67
carbon intensity	kg C/tonne	10.4	5.36	5.31	4.77	4.67	4.67
Clinker Production							
Fuel-Specific							
energy intensity	GJ/tonne	3	0.39	0.33	0.07	0.03	0.03
carbon intensity	kg C/tonne	77.4	10.07	8.52	1.82	0.82	0.82
Sector-Wide							
energy intensity	GJ/tonne	3	0.39	0.33	0.07	0.03	0.03
carbon intensity	kg C/tonne	77.4	10.07	8.52	1.82	0.82	0.82
Cement Grinding							
energy intensity	kWh/tonne	30	8.85	8.59	2.56	2.45	2.45
carbon intensity	kg C/tonne	6.78	2	1.94	0.58	0.55	0.55
PLANT TOTAL:							
Fuel-Specific							
Energy Savings	TJ		1686.6	1567.8	902.9	817.8	817.8
	GJ/tonne cement		1.22	1.14	0.66	0.59	0.59
Carbon Savings	Ktonne		38.4	35.4	19.3	17.2	17.2
	kg C/tonne cement		19.76	18.22	9.94	8.86	8.86
Sector-Wide							
Energy Savings	TJ		1686.6	1567.8	902.9	817.8	817.8
	GJ/tonne cement		1.22	1.14	0.66	0.59	0.59
Carbon Savings	Ktonne		38.4	35.4	19.3	17.2	17.2
	kg C/tonne cement		19.76	18.22	9.94	8.86	8.86

Table 15. Decrease in carbon intensity from CDM projects against baselines (continued)

Project #3			***Energy/carbon reductions relative to various benchmarks*** *(project performs this much lower than benchmark)*				
PROCESSES:		**Project Performance**	Average	Weighted Average	Percentile 25%	Percentile 10%	Best Plant
Raw Material Grinding							
energy intensity	kWh/tonne	46.1	23.63	23.4	21	20.57	20.57
carbon intensity	kg C/tonne	10.42	5.34	5.29	4.75	4.65	4.65
Clinker Production							
Fuel-Specific							
energy intensity	GJ/tonne	3.13	0.26	0.2	-0.06	-0.1	-0.1
carbon intensity	kg C/tonne	80.75	6.72	5.17	-1.53	-2.53	-2.53
Sector-Wide							
energy intensity	GJ/tonne	3.13	0.26	0.2	-0.06	-0.1	-0.1
carbon intensity	kg C/tonne	80.75	6.72	5.17	-1.53	-2.53	-2.53
Cement Grinding							
energy intensity	kWh/tonne	30.1	8.75	8.49	2.46	2.35	2.35
carbon intensity	kg C/tonne	6.8	1.98	1.92	0.56	0.53	0.53
PLANT TOTAL:							
Fuel-Specific							
Energy Savings	TJ		1016.5	932.5	462.7	402.7	402.7
	GJ/tonne cement		0.74	0.68	0.34	0.29	0.29
Carbon Savings	Ktonne		22.7	20.6	9.2	7.7	7.7
	kg C/tonne cement		16.48	14.94	6.69	5.61	5.61
Sector-Wide							
Energy Savings	TJ		1016.5	932.5	462.7	402.7	402.7
	GJ/tonne cement		0.74	0.68	0.34	0.29	0.29
Carbon Savings	Ktonne		22.7	20.6	9.2	7.7	7.7
	kg C/tonne cement		16.48	14.94	6.69	5.61	5.61

Table 15. Decrease in carbon intensity from CDM projects against baselines (continued)

Project #4			***Energy/carbon reductions relative to various benchmarks*** *(project performs this much lower than benchmark)*				
PROCESSES:		**Project Performance**	Average	Weighted Average	Percentile 25%	Percentile 10%	Best Plant
Raw Material Grinding							
energy intensity	kWh/tonne	46	23.73	23.5	21.1	20.67	20.67
carbon intensity	kg C/tonne	10.4	5.36	5.31	4.77	4.67	4.67
Clinker Production							
Fuel-Specific							
energy intensity	GJ/tonne	3	Flag 2	Flag 2	Flag 2	Flag 2	Flag 2
carbon intensity	kg C/tonne	61.65	Flag 2	Flag 2	Flag 2	Flag 2	Flag 2
Sector-Wide							
energy intensity	GJ/tonne	3	0.39	0.33	0.07	0.03	0.03
carbon intensity	kg C/tonne	61.65	25.82	24.27	17.57	16.57	16.57
			Flag 2 indicates that this project is not appropriate for fuel-specific evaluation				
Cement Grinding							
energy intensity	kWh/tonne	30	8.85	8.59	2.56	2.45	2.45
carbon intensity	kg C/tonne	6.78	2	1.94	0.58	0.55	0.55
PLANT TOTAL:							
Fuel-Specific							
Energy Savings	TJ						
	GJ/tonne cement						
Carbon Savings	Ktonne						
	kg C/tonne cement						
Sector-Wide							
Energy Savings	TJ		1686.6	1567.8	902.9	817.8	817.8
	GJ/tonne cement		1.22	1.14	0.66	0.59	0.59
Carbon Savings	Ktonne		66	63	46.9	44.8	44.8
	kg C/tonne cement		33.93	32.39	24.12	23.03	23.03

Table 15. Decrease in carbon intensity from CDM projects against baselines (continued)

Project #5			***Energy/carbon reductions relative to various benchmarks*** *(project performs this much lower than benchmark)*				
PROCESSES:		**Project Performance**	Average	Weighted Average	Percentile 25%	Percentile 10%	Best Plant
Raw Material Grinding							
energy intensity	kWh/tonne	46	23.73	23.5	21.1	20.67	20.67
carbon intensity	kg C/tonne	10.4	5.36	5.31	4.77	4.67	4.67
Clinker Production							
Fuel-Specific							
energy intensity	GJ/tonne	3	Flag 2	Flag 2	Flag 2	Flag 2	Flag 2
carbon intensity	kg C/tonne	45.9	Flag 2	Flag 2	Flag 2	Flag 2	Flag 2
Sector-Wide							
energy intensity	GJ/tonne	3	0.39	0.33	0.07	0.03	0.03
carbon intensity	kg C/tonne	45.9	41.57	40.02	33.32	32.32	32.32
			Flag 2 indicates that this project is not appropriate for fuel-specific evaluation				
Cement Grinding							
energy intensity	kWh/tonne	30	8.85	8.59	2.56	2.45	2.45
carbon intensity	kg C/tonne	6.78	2	1.94	0.58	0.55	0.55
PLANT TOTAL:							
Fuel-Specific							
Energy Savings	TJ						
	GJ/tonne cement						
Carbon Savings	Ktonne						
	kg C/tonne cement						
Sector-Wide							
Energy Savings	TJ		1686.6	1567.8	902.9	817.8	817.8
	GJ/tonne cement		1.22	1.14	0.66	0.59	0.59
Carbon Savings	Ktonne		93.5	90.5	74.5	72.3	72.3
	kg C/tonne cement		48.11	46.57	38.29	37.21	37.21